

DEPENDENCE OF BIOLOGICAL SCATTERING ON ACOUSTIC CARRIER FREQUENCY

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LONG-TERM GOALS

The long-term goals of the Principal Investigators are to continue the development of theory and technology needed to resolve the forward and inverse problems in fisheries acoustics.

OBJECTIVES

To combine acoustic backscatter models with empirical measurements to investigate the utility of multi-frequency data when estimating target size, and when attempting to recognize and discriminate acoustic targets.

APPROACH

Acoustic scatter models are based on digitized x-ray images of fish body and swimbladder morphology. Back-scatter amplitude as a function of acoustic wavelength, fish length, and fish aspect is estimated using Kirchhoff ray-mode scatter models^{1,2}. Model predictions are used in computer simulations to estimate population abundances, and compared to empirical backscatter measurements from tethered fish in tanks and in situ field measurements during mobile surveys.

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WORK COMPLETED

Kirchhoff-ray mode backscatter models have been used to examine: choice of system configurations when selecting sonar equipment for fisheries research³; applicability of model to discriminate co-occurring pelagic species⁴; the combination of multiple frequencies and the inverse approach to estimate abundances of fish within specified size-classes⁵; and to examine orientation and aspect distributions of fish within ensembles^{6,7}.

A computer-controlled aspect frame was designed, constructed, and used to tether fish for acoustic backscatter measurements during a trip to the Huntsman Marine Science Center in St. Andrews, New Brunswick. Acoustic equipment used during tank measurements included single and split-beam single frequency commercial sounders, and a four channel, digital sounder from the University of Wisconsin-Madison. Work is continuing on analysis of x-ray, tank, and field data from the St. Andrews trip.

RESULTS

Kirchhoff-ray mode model predictions match empirical scattering measurements over a wide range of fish lengths and aspects. Model results provide insight to variation in backscatter measurements. Measurements of backscatter by swimbladdered fish are relatively robust when the ratio of fish length to frequency wavelength is between two and ten. As fish length to wavelength ratios increase, echo amplitudes become more dependent on aspect. Amplitudes peak when the swimbladder is perpendicular to the acoustic wavefront.

IMPACT/APPLICATIONS

Morphologically-based scattering models provide a convenient way to quantify the sensitivity of backscattered echo amplitudes to hardware parameters and organism behavior. Scattering models can be used to: explore carrier frequency choices when designing acoustic surveys, acoustically estimate organism abundances in multiple length classes, and to refine the discrimination of fish species in acoustic data.

TRANSITIONS

The Kirchhoff-ray mode backscatter model is currently being used to predict echo amplitudes for a number of fish species throughout the world. Several inquiries have also been received from medical researchers working on human imaging projects. Consultation with the co-PI's of this project aided in the development of a viscous-elastic swimbladder model for describing low-frequency resonant backscatter of fish (C. Feuillade and R. Nero, Naval Research Laboratory, Stennis Space Center).

RELATED PROJECTS

Results from this study have prompted us to initiate several projects to help quantify the variability of physical and biological factors influencing backscattered echo amplitudes: - develop 3-D modeling of fish images (Ken Foote, IMR, Norway) to quantify the sensitivity of model predictions to image resolution.

- use other imaging technologies (e.g. RUTIS and MRI) to enhance delineation of fish swimbladder and body structure.
- measure low frequency (200 HZ - 2 kHz) backscatter for comparison to model predictions (Mardi Hastings, Ohio State University)

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